Technical Basis for Bioassay Requirements

Collider-Accelerator Department

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Facility	Collider-Accelerator Department facilities, see http://www.rhichome.bnl.gov/AGS/Accel/SND/buildingmanagers.htm
Site	Brookhaven National Laboratory
Operating Contractor	Brookhaven Science Associates
Office of Science Program Office	Nuclear Physics
Facility Classification	Low Hazard Accelerator Facility

Purpose

This document provides the technical basis for not including all C-A radiation workers trained in RWT-300 in the BNL routine bioassay program.

Inventory of Radioactive Materials

Uranium Shield Block

Building 912 has depleted uranium shield block. The block is made up of 32 pieces of depleted uranium. It is located in the downstream end of the C3 beam line. The dimensions of each piece are 55.88 cm x 55.88 cm x 10.16 cm. The total mass of the 32 pieces is 17,841.8 kg. The total activity is 9.7 Ci. The depleted uranium is completely encased in concrete shielding.

The uranium shield block was designed to accommodate both shielding and space requirements. The high density of uranium allows the C-A Department to fit the beam-line shielding within the building confines whereas iron, concrete or heavy concrete would require more space than is available.

Activated Beam-line Equipment

During transport through many hundreds of meters of tunnel and accelerators, a small percentage of the beam is lost. This errant beam is shielded with up to 7-m thick earth-roofs and 20-m thick earth-sides. Most accelerated particles end at targets inside heavily shielded target-caves with 3-m thick high-density-concrete walls. About half the proton beam interacts in a target, with the remainder going to the next target downstream or directly to a beam stop. Errant beams interact in items such as magnets, concrete, iron, earth, vacuum pipes and cables. The result is that accelerators and transport tunnels have

localized areas of residual radioactivity in addition to that at target caves. A massive collimator captures beam diverging from the first of two targets placed in tandem in one of the beam-lines. This significantly reduces widespread activation of downstream magnets and magnet cooling-water.

When a high-energy proton interacts with a nucleus, many secondary particles are emitted which have a high enough energy to produce further particles, thus creating a nuclear particle cascade. An array of secondary particles called hadrons (p, n, π) are produced, and they in turn produce radionuclides through inelastic nuclear reactions.

The materials used in the construction of the accelerators are limited in number, the most important being Fe, Cu, Al and concrete. The important radionuclides from a bioassay standpoint are ^{3}H, ^{7}Be, ^{22}Na, and ^{60}Co. Measurements indicate that residual long-lived gamma-activity per unit mass ranges from 1 to 5 nCi g^{-1}. Surface contamination from these materials was measured to be negligible; that is, less than 100 dpm per 100 cm^{2}.[1] The predominant nuclide is ^{60}Co, which has a 5.3-year half-life. It is estimated that ^{3}H is present at 1 nCi g^{-1} or less.[2] Other radionuclides produced by activation of beam-line equipment are too short-lived for bioassay to be considered.

It is important to know that induced radioactivity is deeply entrained in materials due to the penetrating ability of the initial accelerated particles. Residual radioactivity is not readily dispersible to the environment, even in a fire.

Activated Air

By design, airborne emissions from the accelerators are not directed to an emission point such as a stack or vent during routine operations. Linac, Booster and AGS work fine during operations with re-circulating air-conditioning systems. In the experimental areas, trace amounts of short-lived airborne radioactivity are observed near target-cave gates although there is no air-moving system in these beam lines. Activation of air in experimental beam lines is minimized by ensuring the path of beams in air is minimized. This is done by keeping the beam inside vacuum lines.

Typical gross-beta airborne-radioactivity concentration near target-cave gates is 1x10^{-8} μCi cm^{-3} or less. A total immersion dose-rate from airborne radioactivity near a gate is estimated to be about 0.2 mrem h^{-1} with 2x10^{13} p s^{-1} of beam on a typical target.[3] The

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[1] RCD contamination surveys of C-A beam lines; see Attachment 1 for example.

[2] Lessard, E. T., Characterization of Low Level Radioactive Waste From the AGS Complex Including An Assessment of Pure Beta (b) Emitters, Informal Report, Submitted to S&EP Division at the Request of the Hanford Site, AGS Department, Brookhaven National Laboratory, Associated Universities, Inc., Upton, New York 11973, November 1, 1995. (http://www.rhichome.bnl.gov/AGS/Accel/SND/Bioassay/PureBetaEmitters.pdf)

[3] Lessard, E. T., Environmental and Safety Issues Associated With a 30 GeV Accelerator Complex, Proceedings of the Fifteenth International Conference on the Application of Accelerators in Research and Industry, Ed. by Jerome Duggan and I. Lon Morgan, University of North Texas, Denton, TX 76203, Nov. 4-7, 1998. (http://www.rhichome.bnl.gov/AGS/Accel/SND/Presentations/EnvironmentIssuesAGS.pdf)

corresponding fraction of an immersion DAC (Derived Air Concentration) is 0.08. Most of the immersion dose rate is attributed to ^{15}O, which has a 2.1 minute half-life, although ^{3}H, ^{7}Be, ^{11}C, ^{13}N, ^{14}O, ^{41}Ar are present. Gross-beta airborne-radioactivity is not measurable more than a few meters beyond the target-cave gates, and is not considered to pose a significant intake hazard. Due to the low concentrations and/or short half lives, these airborne nuclides would not be detected by routine bioassay techniques.

Activated Water

Activated cooling-water systems contain ^{3}H. About 75,000 gallons of cooling water is contained in the activated closed-looped cooling systems. Total ^{3}H activity is about 100 mCi. Optimizing beam transport through beam-line components minimizes activation. Levels of ^{3}H activity-concentration range from $2x10^{-5}$ to $5x10^{-3}$ μCi cm^{-3}. The International Commission on Radiological Protection (ICRP Publication 30) lists a dose conversion factor that translates into about 1 mrem for an intake of 200 gallons of water with a tritium concentration at $2x10^{-5}$ μCi cm^{-3}. An intake of 200 gallons at $5x10^{-3}$ μCi cm^{-3} translates into about 230 mrem. We note that two hundred gallons is the total fluid intake for an adult male in one year. Thus, at the observed concentrations, exposure to tritiated water at C-A Department does not qualify an individual for routine bioassay.

Targets and Stops

Target caves or beam lines just upstream of target caves tend to be the locations where the highest level of residual gamma-radiation and contamination are measured.[4] Typical contamination levels are observed to range from several hundred to several thousand dpm β per 100 cm^2 for targets in Buildings 912 and 949 (V Target). Target caves contain items similar to items found in transport tunnels; in addition, they shield the targets, targets that are several hundred grams of Pt or Cu, or several kilograms of Ni. Traces of short-lived ^{39}Cl and ^{38}Cl are observed in air outside target cave gates. These two gaseous radionuclides are produced due to beam interaction with the target material. High-intensity targets have secondary containment to trap Cl spallation-products. At the observed concentrations, these airborne radionuclides cannot be detected by routine bioassay techniques.

On the other hand, Building 930 houses the BLIP spur that is a higher-level contamination area found in the Linac. The BLIP spur is used to transport high intensity protons to a Medical Department facility for the production of radioactive materials that are later processed into radiopharmaceuticals. Levels of contamination on the outer surface of vacuum pipe at the end of the beam line are typically 10,000-dpm β per 100 cm^2, and higher levels are observed inside the vacuum pipe or on the surface of damaged vacuum windows. The floor is usually but not always contamination free. This spur is isolated by a locked gate, and work that causes the dispersal of contamination is normally performed by Medical Department personnel who are in a bioassay program.

[4] RCD contamination surveys of C-A target cave; see Attachment 2 for example.

With the exception of the BLIP facility, the uncollided protons escaping the target will stop in iron beam stops that are 20-m long or equivalent. The resulting long-lived radionuclides, ^{3}H and ^{22}Na, are produced at mCi levels and are deeply entrained in the iron stop and in the soil shield surrounding the stop. Because of the lower energy of the bombarding particles, the BLIP facility uses several feet of silica-based grout material as a beam stop. There are no airborne emissions from beam stops.

The uranium shield block forms the downstream portion of the C3 beam stop. Typical C-A Department fixed-target beam-stops use a combination of concrete and iron shield blocks to stop the hadrons and leptons that are produced in the forward direction of nuclear cascades. The C3 beam stop starts with 1.5 m of concrete and is followed by 11 m of iron. About 3 m of uranium shield block follows the iron, which in turn is followed by 1.5 m of concrete. Because the uranium is located near the end of the stop, it does not see significant levels of hadrons. The uranium is used to stop the more penetrating leptons, which are muons and high-energy electrons, and these particles do not have nuclear interactions. Thus, the uranium portion of the beam stop is not activated.

Intake History

On May 8, 1998, upon exiting the BLIP spur at Linac, which is the most contaminated area within C-A facilities, a vacuum technician noticed that the knee area of his protective clothing (PC) was torn. A survey of the hands and clothing showed about 50 $\mu R\ h^{-1}$ at contact on the knee of his pants, just beneath the torn area of the PC. Contamination was also found on the hand. Contamination of the floor was attributed to occur during vacuum pipe replacement work performed three days before May 8, 1998 by Medical Department personnel. The levels on the knee of the street pants were 100,000-dpm β per 100 cm^2. The dose to the hand and knee were estimated to be essentially zero. The nuclide was identified as ^{22}Na. No intake resulted.

On March 17, 1995, the B5 target broke during a high intensity run and the failure was due to repeated thermo-mechanical stresses from the pulsed beam. Immediately following this target failure, it was discovered that the gate leading to B5 target was contaminated at about 80,000 dpm per 100 cm^2. The levels outside this gate had been 200 to 1000 dpm per 100 cm^2 routinely due to deposition of short-half-life (20 to 30 minutes) air-activation products, and the location had been roped-off as a Contamination Area. Unnoticed by Radiation Control Technicians, a virtually undetectable gaseous emanation from the overheated B5 target had spread beyond the Contamination Area. The nuclides were ^{185}Os and ^{7}Be and they had spread to an experimenter occupied area where they were first detected on March 27, 1995. Osmium-185 (95-day half-life) and ^{7}Be do not emit beta radiation so they were not picked up on smear surveys. They were not readily distinguishable from the ambient levels of gamma radiation normally measured in the these areas during operations. The contamination was discovered when equipment being returned to an experimenter's home institution was checked for inadvertent activation. This checking is done by transporting experimenter's equipment to a low background area. After whole-body counting all the experimenters and staff

who worked in the area from March 17 to March 27, 1995, it was found that the contamination resulted in five persons experiencing an intake. The highest body-burden was about 120 nCi, and the highest committed dose was estimated to be less than 10 mrem. Four experimenters were found to have body burdens of 50 to 90 nCi of ^{185}Os and ^{7}Be. This was interpreted as a committed dose of about 4 mrem. Other personnel involved in the target replacement and clean-up were whole-body counted but no further intake was observed.

On the evening of April 7, 1992, contamination was found on four Vacuum Group individuals who were working in the BLIP spur in Linac. The findings on clothing were 1000 to 15,000 dpm. The ^{22}Na contamination was found after one of the four Vacuum Group Technicians injured his hand. No intakes occurred.

The frequency of spills from tritiated cooling-water systems is minimized by choosing system components suited to the differential pressures involved. A hose or pipe break or a seal failure occurs about once every 4 years at a level that releases more than 100 gallons of activated water. Cooling-system makeup water is monitored by computer and alarmed in the Main Control Room, which is manned round-the-clock during operations periods. Pumps automatically turn-off when a leak is detected. Operators responding to alarms are trained to properly handle tritiated water. Personnel contamination from tritiated cooling water spills has not been observed.

Before 1987, records of intakes are sparse. Beam intensity was several orders of magnitude less, but some uncontained targets such as tungsten targets were reported to disperse easily. Tungsten targets are no longer used.

Process or Activity Descriptions

The uranium shield blocks and the activated beam-line materials are not "in process" in any manner. Activated beam-line components and shield block sit passively in the beam lines.

About 20 tritiated cooling-water systems are distributed throughout the magnet enclosures. A network of floor drains collects leaks. Tritiated water inadvertently entering the floor-drain system is conducted to the sanitary-sewer system or is collected in sumps. In cases where water is collected in sumps, automatic pumps are turned off and sumps are alarmed. Sump water is pumped by trained staff into tankers and sampled before disposal.

Because discharge to sanitary above the Drinking Water Standard (DWS) is not allowed by the Laboratory, activated water is retained in tankers during maintenance of cooling-water systems and returned to cooling-systems whenever possible. Some tritiated water is transferred to Waste Management Division for processing. This routine processing keeps tritium inventory at a minimum at C-A Department facilities. Additionally, accelerator air-conditioning systems produce condensate that contains ^{3}H due to

activation of air. Radioactive condensate is not handled directly by staff but is released through piping to the sanitary system.

Activated water in cooling-towers in experimental areas is exposed to air as it moves about 10 m above the ground through a tower. The short-lived gamma emitting dissolved radio-gases ^{14}O, ^{15}O, ^{13}N and ^{11}C are present and measurements indicate a transfer to air of about 0.04%.[5] External dose rates due to this emission are barely above natural background levels, which is 5 to 10 $\mu R\ h^{-1}$. At the observed concentrations, these airborne nuclides cannot be detected by routine bioassay techniques.

Work Planning Process In Radiological Areas

Brookhaven National Laboratory and the Collider-Accelerator Department have put into practice a series of management systems to help ensure that work is done in a safe and environmentally conscientious manner. These management systems detail the processes and procedures that are associated with different types of work and are available to everyone via the BNL Standard Based Management Systems (SBMS) internet web site. SBMS is BNL's method for implementing the Integrated Safety Management System (ISM). ISM combines environmental, safety and health requirements into the process for planning and conducting work at the Laboratory. All physical work activities are governed by the Work Planning Process. All internally initiated jobs at C-A Department are examined for ES&H hazards. Work Permits are required for all moderate and high hazard jobs, and screening is required to distinguish the low-hazard jobs. Any work in a radiological area requires both a Work Permit and a Radiation Work Permit (RWP). In addition, simple entry into any radiological area at the Collider-Accelerator complex must follow the requirements of an RWP. Attendance at program-specific training courses makes C-A Department personnel, users and guests familiar with entry RWPs. Job Specific RWPs are used to control operations or work in areas with changing radiological conditions. It is noted that Job-Specific RWPs apply to specific individuals for all jobs in Contamination Areas. Facility Support Personnel evaluate the need for bioassay in Contamination Areas at the time Job-Specific RWPs are written.

[5] Lessard, E. T., K. Reece, and R. Miltenberger, Radiation Protection Studies During High Intensity Running At AGS, Radiation Exposure Around The AGS Ring And In The SEB Experimental Areas, AGS Department Technical Note #414, Brookhaven National Laboratory, Associated Universities Incorporated, Upton, New York, 11973, March 1995.
(http://www.rhichome.bnl.gov/AGS/Accel/SND/Bioassay/TechNote414.pdf)

Intake Assessment

Assessment of Intake Due to Normal Operations

Category	Potential Internal Exposure	Basis
Inhalation	Less than 1 mrem	Resuspension
Intake through skin	None	Experience
Ingestion	None	Trained Workers

Posted Contamination Areas at C-A are few in number and small in size, much less than 50 m^2. They exist primarily adjacent to fixed target locations. Routine contamination levels are modest, and dispersible radionuclides are associated with the outer surfaces of activated beam line components and concrete shielding. The principal modes of decay are β^-, β^+, and electron capture. The inventory does not include any alpha-emitters.

The following table shows that the likely internal exposure for a one-hour entry into a typical C-A Contamination Area will result in less than 1 mrem of internal exposure per worker. External exposure rates dictate the time one spends near a fixed target, and this time is typically much less than 1 hour. This analysis is based on contamination levels observed during high-energy physics running when fixed target external exposure rates are at their highest level. Also assumed were: a uniform contamination area of 50 m^2, a resuspension factor of 0.001, and a work-area air-volume of 1.2 E8 cm^3.

	ALI, μCi	dpm per 100 cm^2	Total Activity, μCi	Resus-pension Factor	Air volume, cm^3	Volume Breathed, cm^3	Potential Internal Dose, mrem
Be-7	19,200	20,000	45	0.001	1.2E8	1.2E6	0.0001
Na-22	600	5000	10	0.001	1.2E8	1.2E6	0.0009
Mn-54	800	5000	10	0.001	1.2E8	1.2E6	0.0007
Co-57	700	5000	10	0.001	1.2E8	1.2E6	0.0008
Co-60	30	1000	2.25	0.001	1.2E8	1.2E6	0.00375

The maximum number of entries into these areas is likely to be less than ten. Therefore, it is not expected that any one individual will exceed 1 mrem of internal exposure resulting from routine operations.

Assessment of Intake Due to Accidents

Category	Potential Internal Exposure	Basis
Inhalation	Less than 600 mrem	Fire
Ingestion	None	Trained Workers

The following is a discussion pertaining to potential dispersal of activated Fe, Cu, Al, concrete, target materials or depleted uranium. There is no issue of criticality. Solid activated materials and the depleted uranium are encased in concrete shielding. This analysis considers the possibility of a fire or an overheated target. No other mode of dispersal warrants consideration.

Normal uranium is a combustible metal. Metallic uranium in massive form such as in the form of shield block does not present a significant fire risk unless exposed to a severe and prolonged external fire. Once ignited, massive uranium metal burns very slowly. A 1-inch diameter rod requires about 1 day to burn out after ignition. In the absence of strong drafts, uranium oxide smoke tends to deposit in the immediate area of the burning metal.

There are no combustible materials or ignition sources near the uranium shield block. The block is also encased in concrete, and a fire with subsequent inhalation is not considered possible.

Should a fire start the onsite Fire Department would respond within minutes. Even if the uranium ignited, the slowness with which it burns would not allow significant radiological or toxicological hazards to develop before the fire was extinguished.

On a basis of a review of inhalation exposures at NRC-licensed and DOE-owned facilities, experience with accidental intakes has been such that workers who are closest to the point of release receive the highest internal radiation exposure. [6, 7, 8, 9, 10]

In accidents involving the release of radioactive materials, experience has been that the magnitude of the maximum inhalation intake is about one-millionth, 10^{-6}, of the amount of unsealed material being processed.[11, 12] This empirical approach is applicable for

[6] A. Brodsky, J. Schubert, S. Yaniv, K. Lamson, N. Wald, R. Wechsler and R. Caldwell, "Deposition and Retention of ^{192}Ir in the Lung After an Inhalation Incident," Abstracts of the Health Physics Annual Meeting, June 18-22, 1967, Pergamon Press, 1967.

[7] D. A. Cool, W. S. Cool, A. Brodsky, and G. G. Eadie, "Estimation of Long-Term Biological Elimination of Insoluble Iridium-192 from the Human Lung," Health Physics 33, pp.629-632, 1979.

[8] W. D. Norwood, Health Protection of Radiation Workers, Charles C. Thomas, Springfield, IL, 1975.

[9] National Council on Radiation Protection and Measurements, Management of Persons Accidentally Contaminated with Radionuclides, NCRP Report No.65, NCRP Publications, P. O. Box 30175, Washington, DC 20014, 1980.

[5] A. P. Hull, "Preliminary Dose Assessment of the Chernobyl Accident, Parts I-III," The Health Physics Newsletter, Vol. XIV No.12 and Vol. XV No.1 and No.2, Health Physics Society, 1340 Old Chain Bridge Road, Suite 300, McLean, VA 22101, 1986-1987.

[11] A. Brodsky, "Determining Industrial Hygiene Requirements for Installations Using Radioactive Materials," American Industrial Hygiene Association Journal 26, pp.294-310, May-June 1965 and Health Physics 38, pp.1155-1171, June 1980.

processes that confine radioactive material within an enclosure. Examples are a glove box [13], hood, ion exchange column [14] or pellitizer within a glove box [15]. It is noted that in the C-A Department case, the radioactive material is enclosed in or encased in concrete shielding but it is not in process. However, we assume for the purpose of analysis that a fire is sustainable and that some uranium or activated material is burned, and that this burned portion is "in process." It is important to note that the fraction 10^{-6} applies to inhalation intakes only, and that this is the likely mode of intake for trained employees.

If the uranium block or the beam-line equipment was involved in a fire; that is, the surface of the uranium block or the equipment was burned, then oxidized surfaces could become airborne. Given the paucity of combustible materials in beam lines and the short response time for BNL's professional fire fighters, we conservatively assume 10 kg of activated material or uranium shield block is consumed by fire. If 10 kg is burned, then the empirical approach would indicate a maximum intake by an unprotected individual on the order of 10 mg by inhalation.

The toxicological hazard from depleted uranium is greater than the radiological hazard. Maguire [16] lists the following intakes and possible effects: 8.6 mg causing transient renal injury; 45 mg causing permanent damage; and 240 mg causing 50% lethality. Thus, the intake would not likely to lead to kidney impairment.

The committed effective dose equivalent from inhalation of 10 mg of U (Class Y) is about 600 mrem. The committed effective dose equivalent from inhalation 10 mg of beam-line materials containing ^{60}Co (Class Y) at a concentration of 5 nCi g^{-1} is about 0.01 mrem.

Targets are water cooled and consumption in a fire is not likely, but overheating is possible. Based on experience with an overheated platinum target in the B5 line in 1995, a target that reached a temperature greater than 1000 ^{o}C, the highest body-burden observed was 120 nCi, and the highest committed effective dose equivalent from internal exposure was less than 10 mrem. Since that event, high-intensity target temperatures are closely monitored and new designs have more effective cooling and containment.

Conclusion

Based on experience and analysis, not all C-A radiation workers trained in RWT-300 need to participate in the BNL routine bioassay program. Routine internal dose

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[12] A. Brodsky, "Resuspension Factors and Probabilities of Intake of Radioactive Materials in Process (or 'Is 10^{-6} a Magic Number in Health Physics?)", Health Physics 39, pp.992-1000, 1980.

[13] A. Brodsky, N. Wald, R. E. Lee, J. Horm and R. Caldwell, "Americium Contamination Aspects of a Drybox Incident Involving Hand Amputation" in Health Physics Operational Monitoring, Volume 3, Edited by C. A. Willis and J. S. Handloser, Gorden and Breach, NY, pp.1581-1600, 1972.

[14] R. C. Thompson, Editor, "1976 Hanford Americium Exposure Incident," Special Issue, Health Physics 45, October, 1983.

[15] A. Brodsky, N. Wald, I. S. Horm and B. J. Varzaly, "The Removal of ^{241}Am from Humans by DTPA," Health Physics 17, p.379, 1969.

[16] S. A. McGuire, "A Regulatory Analysis on Emergency Preparedness For Fuel Cycle And Other Radioactive Material Licensees," NUREG 1140, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555, 1985.

equivalent is expected to be much less than 1 mrem per year. Accidental intakes from a fire involving activated beam-line equipment or targets are expected to result in less than 10 mrem per event. If a highly improbable fire involved uranium shield block that is encased in concrete, then the maximum internal exposure is estimated to be about 600 mrem. One concludes that there is no significant acute intake posed either by routine operations or by an accident. Should unexpected internal exposure occur because of fire or target failure, an evaluation will be performed as part of the critique to determine who will need whole body counts or other types of bioassay.

The Collider-Accelerator Department commits to BNL's Special Bioassay program when required. In the Special Bioassay case, Facility Support staff assigned to C-A will identify workers for inclusion in a bioassay monitoring program if any of the conditions identified in FS-SOP-4025 Attachment 8.4 exist.

Finally, a fraction of contamination trained C-A workers, 4 to 5 persons, will be sent for whole body counts each year. Facility Support staff assigned to C-A will identify a representative sample of workers who have potential for maximum intake in order to verify radiological controls continue to be effective at C-A facilities.

Attachment 1

BNL RADIOLOGICAL SURVEY FORM

Bldg. #: 912 ❑ Routine N/A
Location: Switchyard D/S ❑ Special
Date/Time: 10-13-00 / 1450 ☒ RWP#

Smear Survey Results (DPM/100cm²)

	^{3}H	β-γ	α		^{3}H	β-γ	α
1.	44	floor		16.			
2.	LMDA	floor		17.			
3.	LMDA	floor		18.			
4.	31	floor		19.			
5.	LMDA	floor		20.			
6.	LMDA	floor		21.			A
7.	LMDA	floor		22.			
8.	31	floor		23.		N	
9.	LMDA	floor		24.			
10.				25.			
11.			A	26.			
12.				27.			
13.	N			28.			
14.				29.			
15.				30.			

Masslinn Survey Results (DPM/LAS)

1.		8.			
2.		9.			
3.		10.	A		
4.		11.			
5.	N	12.			
6.		13.			
7.		14.			

Dose Rates (Highest)		Airborne Contamination		
Contact	N/A	Time	µCi/cc	%DAC
General Area	N/A	A	N/A	

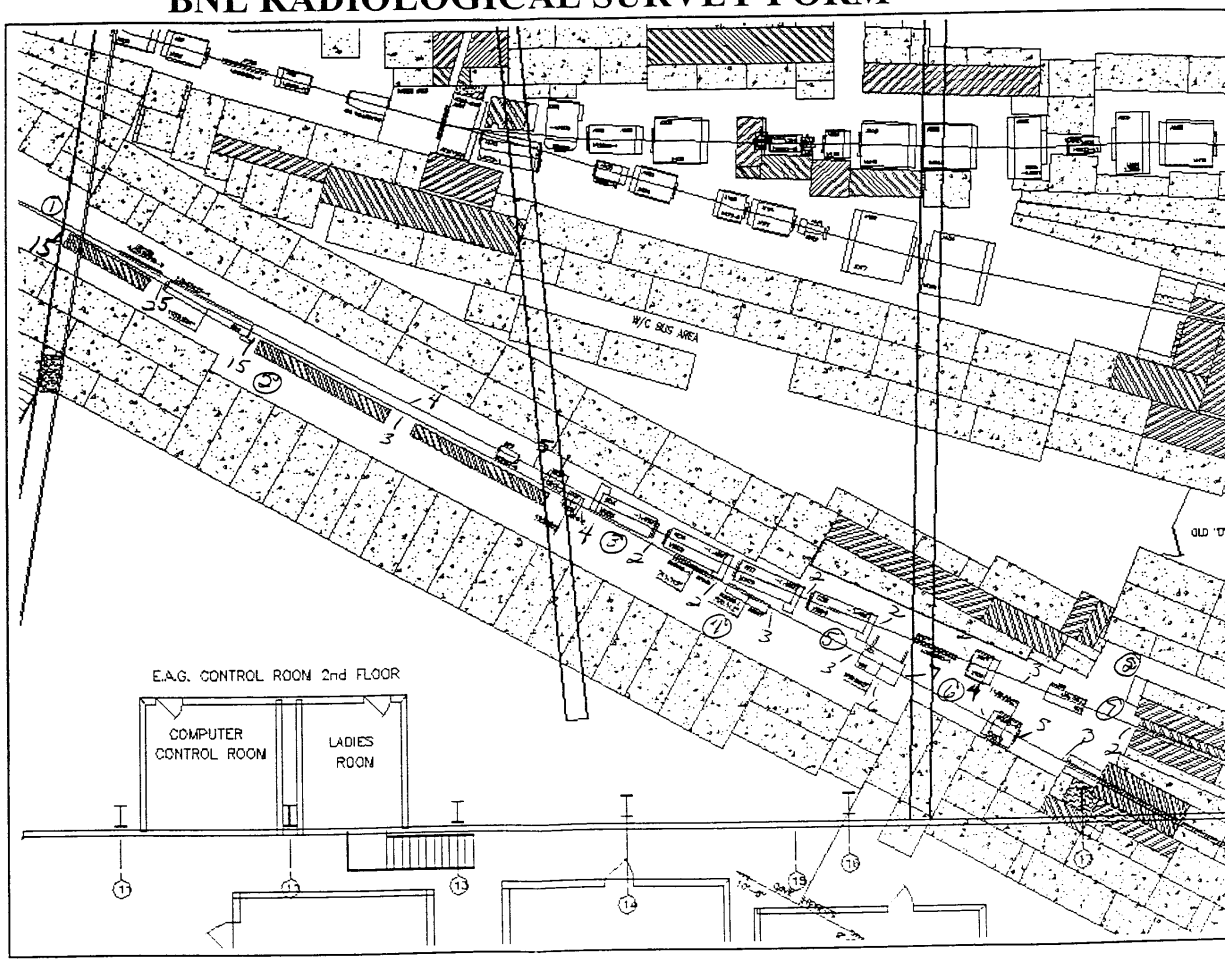
Legend: ● Smear Location ■ Masslinn Location ▲ Airborn

xxx y
zzz

xxx=Contact Reading
zzz=Reading@ 30cm
y= Radiation Type

☒ All Dose Rates are in mR Hr and taken at ~~waist level unless otherwise noted.~~ at 12" (30cm).

Model	Tel	LB5100	
Serial #	37333	32851	A
Cal Due Date		11-9-00	N
Source Check O.K. (yes or no)	Yes	Yes	



Balch # 1134 (17-25)
MDA - 24.7 dpm

Surveyed By: [signature] 10-13-00
Signature Date

Reviewed By: [signature] 10/13/00
Signature/Date

Form FS-1000.1
FS-SOP-1000, rev1, attch. 8.2, page 11
File Code: HP3120

Attachment 2

BNL RADIOLOGICAL SURVEY FORM

Bldg. #: 917 ☐ Routine N/P
Location: C2 Upstream ☐ Special N/A
Date/Time: 9-27-2000 16:00 ☒ RWP#

Smear Survey Results (DPM/100cm²)

	^{3}H	β−γ	α	
1	165	Floor	1907	Floor
2	515	Floor	3650	Floor
3	540	Floor	2037	Floor
4	93	Floor	489	Floor
5	58	Floor	597	Floor
6	160	Floor	891	Floor
7	152	Floor	36	Floor
8	125	Floor	803	Floor
9	436	Floor	766	Floor
10	751	Floor	1563	Floor
11	331	Floor	110	Floor
12	1808	Floor	53	Floor
13	5184	Floor	152	Floor
14	2712	Floor	1092	Floor
15	2114	Floor	170	Floor

Smear ~~Masslinn~~ Survey Results (DPM/~~1.45~~ 100 cm²)

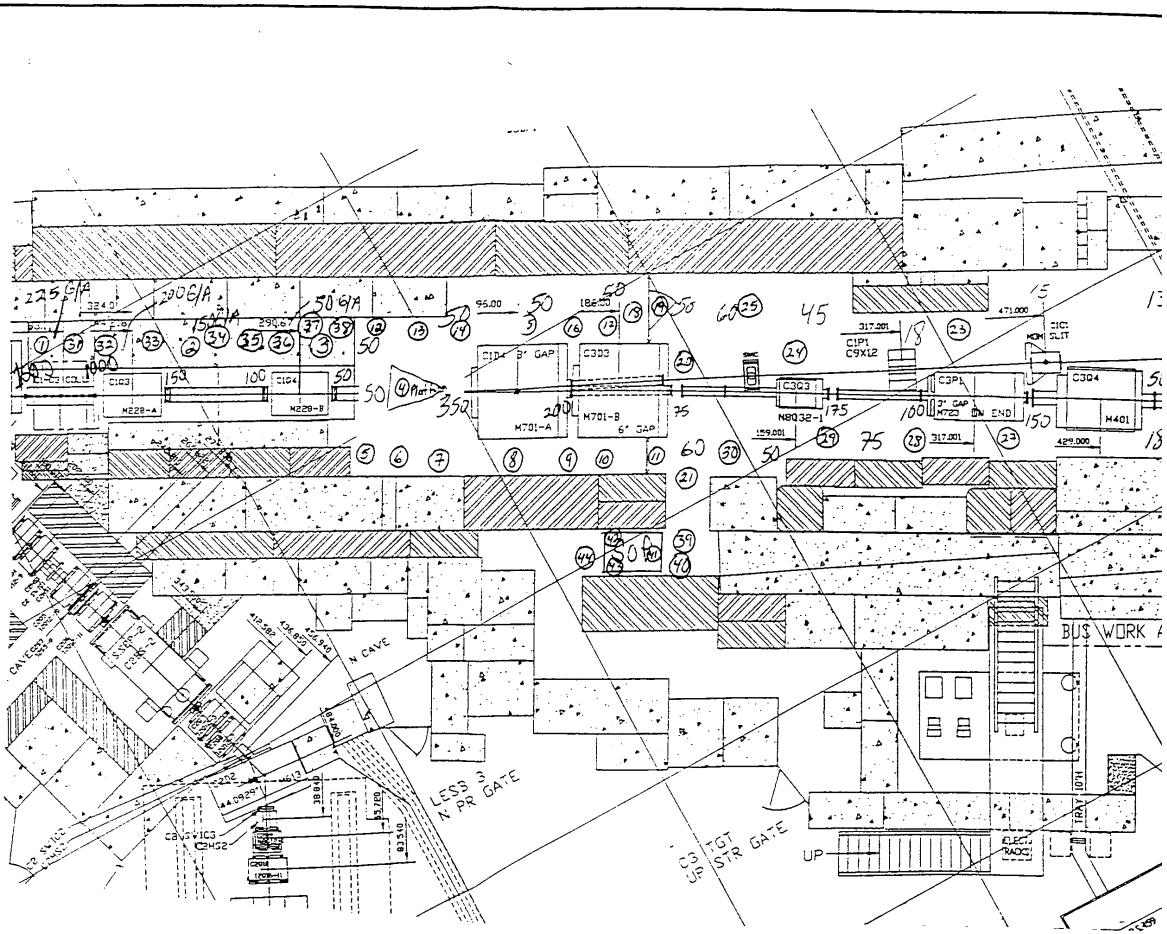
31	152	Floor	38	689	Floor
32	2900	Floor	39	78	Floor
	160	Floor	40	41	Floor
	261	Floor	41	28	SOP
35	329	Floor	42	77	SOP
36	167	Floor	43	26	SOP
37	85	Floor	44	80	Floor

Dose Rates (Highest)		Airborne Contamination		
Contact	N/A	Time	uCi/cc	%DAC
General Area	75mR/hr	N/A	N/A	N/A

Legend: ● Smear Location ■ Masslinn Location ▲ Airborn
xxx=Contact Reading
zzz=Reading@ 30cm
v= Radiation Type
xxx v / zzz

☒ All Dose Rates are in mR/Hr and taken at waist level unless otherwise noted.

Model	Rle	LB5100	
Serial #	81143	32931	
Cal Due Date	5-17-2001	12-22-00	N/A
Source Check O.K. (yes or no)	Yes	Yes	N/A



Surveyed By: [signature] 9-28-2000
Signature/Date

Reviewed By: [signature] 9/29/00
Signature/Date

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